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ON DEVELOPABLE AND TUBULAR SURFACES HAVING SPHERICAL LINES OF CURVATURE.

BY PROFESSOR VIRGIL SNYDER.

(Read before the American Mathematical Society, April 30, 1904.)

IT has been shown by Peters * that if the asymptotic lines of the second system on a scroll belong to linear complexes, the scroll must have two rectilinear directrices. This theorem, interpreted in spherical space becomes: If an annular surface has plane or spherical lines of curvature of the second system, the spheres or planes must all belong to a pencil.

In particular, if the theorem be applied to developable surfaces, the generating planes of the latter must belong to a linear spherical complex

$$\psi \equiv a\xi + b\eta + c\zeta + d\lambda + e\mu + f\nu = 0,$$

as well as to the complex of planes

$$\Pi \equiv \mu - \nu = 0.$$

The generating planes must touch the directrices of this congruence, which are two concentric spheres; or, if $e + f = 0$, the fundamental sphere of every complex of the pencil becomes a plane, and these planes are parallel.

The necessary and sufficient condition that the planes belong to a complex E $(e + f = 0)$ is that the variable coefficients $u(t)$, $v(t)$, $w(t)$, $s(t)$ in the equation of the generating plane

$$ux + vy + wz + s = 0$$

satisfy a relation of the form

$$Au + Bv + Cw = D\sqrt{u^2 + v^2 + w^2}\sqrt{A^2 + B^2 + C^2}.$$

* "Die Flächen, deren Hauptiangentenkurven linearen Complexen angehören," Christiania [Leipzig dissertation, 1895].

Let the plane containing a line of curvature be chosen for the (x, y)-plane. $A = 0$, $B = 0$, so that the relation becomes

$$u^2 + v^2 = lw^2.$$

The equation of the plane may be written

$$z + \frac{u}{w}x + \frac{v}{w}y + \frac{s}{w} = 0.$$

Let

$$u/w = \tau, \qquad v/w = \sqrt{l - \tau^2};$$

then the equation of the generating plane becomes

$$z + \tau y + \sqrt{l - \tau^2}\,x + \phi(\tau) = 0,$$

in which $\phi(\tau)$ is an arbitrary function of τ.

If the curved lines of curvature of a developable surface are plane, the planes are parallel. If these planes be of the form $z = c$, the developable is the envelope of the plane

$$z + \sqrt{l - \tau^2}\,x + \tau y + \phi(\tau) = 0.$$

Let the parameter τ and the function $\phi(\tau)$ be replaced by a new parameter k and a function $f(k)$ defined by the equation

$$\phi(\tau) = k\tau + f(k)\sqrt{l - \tau^2}.$$

No restriction is placed upon the old or the new function by this substitution. Differentiate as to τ,

$$\phi'(\tau) = k - \frac{\tau f(k)}{\sqrt{l - \tau^2}},$$

and substitute the result in the derivative of the generating plane,

$$0 = \frac{-\tau}{\sqrt{l - \tau^2}}x + y + \phi'(\tau).$$

Thus

$$\frac{\tau}{\sqrt{l - \tau^2}}x - y = k - f(k)\frac{\tau}{\sqrt{l - \tau^2}},$$

from which

$$(k+y)^2 = \frac{\tau^2}{l-\tau^2}\big(f(k)+x\big)^2,$$

or, solving for τ,

$$\tau = \frac{\sqrt{l}\,(y+k)}{\sqrt{(x+f(k))^2+(y+k)^2}},$$

$$\sqrt{l-\tau^2} = \frac{\sqrt{l}\,(x+f(k))}{\sqrt{(x+f(k))^2+(y+k)^2}}.$$

These values are now to be substituted in the equation of the generating plane

$$z + \sqrt{l-\tau^2}\,x + \tau y + \phi(\tau) = 0.$$

The result may be written

$$z^2 = l\big[(x+f(k))^2 + (y+k)^2\big].$$

The surface is thus seen to be the envelope of a right circular cone of constant angle, whose axis is always perpendicular to the plane lines of curvature, but whose vertex describes an arbitrary plane curve. The plane sections $z = c$ are seen also to be the envelope of a circle of fixed radius c whose center describes the curve

$$\alpha = -f(k), \qquad \beta = -k;$$

hence the lines of curvature in the planes $z = c$ project orthogonally into a system of parallel curves.

Minimum developables and the developables whose cuspidal edges are general helices are included in this category; but others whose cuspidal edges are not helices are also included.

Similarly, if the lines of curvature are spherical the spheres must be concentric. All of the generating planes are tangent to a sphere along any arbitrary curve. If the planes all pass through a point the surface reduces to a cone.

If the center of the family of concentric spheres is taken as origin, the parameter τ of the generating plane must satisfy the relation

$$s^2 = r^2(u^2+v^2+w^2),$$

so that here two coördinates are arbitrary. The equation of the plane may be written

$$\tau x + \phi(\tau)y + \sqrt{k^2 - \tau^2 - \phi(\tau)}\, z = 1;$$

or also

$$\sqrt{[k\phi(\tau)]^2 - 1 - \tau^2}\, x + \tau y + z = \phi(\tau).$$

A tubular surface is the envelope of a sphere of constant radius whose center describes an arbitrary curve. If the lines of curvature of such a surface are to be plane or spherical, the surface must be contained in the congruence

$$d'\lambda + e'(\mu - \nu) = 0,$$

$$\psi \equiv a\xi + b\eta + c\zeta + d\lambda + e\mu + f\nu = 0.$$

The directrices of this congruence are two spheres concentric with the fundamental sphere of $\psi = 0$, and the locus of centers is therefore a sphere. Hence when the lines of curvature of a tubular surface are spherical, the locus of centers must be a spherical curve. The curves of intersection made with the surface by the pencil of spheres concentric with that of the locus of centers are their lines of curvature.

If in ψ $e + f = 0$, the fundamental sphere becomes a plane. The directrices are in this case two parallel planes and the locus of centers becomes a plane curve. The lines of curvature are now in a series of parallel planes, as is also geometrically evident.

The theorem regarding developables is thus at once applicable to tubular surfaces.

The section made by the plane at infinity with any tubular or developable surface is always a line of curvature. If the surface contains one other plane (or spherical) line of curvature, then all lines of the system must also be plane (spherical). For a treatment of the general annular surface having spherical lines of curvature see two papers by the author in the *American Journal of Mathematics*, volumes 22 and 23.

When a surface has one system of lines of curvature, lying in parallel curves, the other system is plane also and the projection of the lines of both systems upon a plane parallel to the former will be an orthogonal system. The converse is also true, namely:

Surfaces whose lines of curvature of both systems are orthogonally projected into an orthogonal system on a plane are surfaces having one system of lines of curvature lying in parallel planes.

Since then all the lines of curvature of both systems belong to spherical complexes whose fundamental spheres become planes, and the planes of one system cut both the surface and the planes of the parallel system orthogonally, the parallel planes are fundamental spheres of a system of complexes of the form

$$c\zeta + d\lambda + e(\mu - \nu) = 0,$$

in which without loss of generality $c = 1$, $d = \tau$, $e = f(\tau)$. In particular, if $f(\tau)$ is a linear function, the surface is either a tube or a developable.

In the general case, the other system of lines of curvature belong to the complexes

$$a\xi + b\eta - h(\mu - \nu) = 0,$$

in which $a = 1$, $b = k$, $h = \phi(k)$. If $f(\tau)$ is not linear, $\phi(k)$ cannot be linear.

The first system of complexes have in common one set of generators of a Dupin's cyclide. The second system contains the other set of generators.

The discriminant (invariant) of the characteristic cyclide vanishes, but not all of the first minors vanish. The cyclide therefore reduces to a gauche quadrilateral of minimum lines. This same property will also hold for every surface into which the surface may be transformed by inversion in a linear complex.

The lines of curvature of any inversion of a moulded surface are spherical in both systems, and the characteristic Dupin's cyclide degenerates into a gauche quadrilateral of minimum lines.

When all the lines of curvature of both systems are plane, the characteristic Dupin cyclide must consist of planes in both generations. It was shown by Bonnet that the planes containing the lines of curvature of one system are tangent to a cylinder, and those of the other system tangent to another cylinder whose axis is perpendicular to that of the first.

If $x = 0$, $y = 0$ be the equations of the first axis, the net of complexes to which the lines of curvature of the first system belong may be written in the form

$$E + \theta E' + \iota E'' = 0,$$

where

$$E^i \equiv a^i\xi + b^i\eta + d^i\lambda + e^i(\mu - \nu)$$

and

$$\Sigma aa' = 0, \qquad \Sigma aa'' = 0, \qquad \Sigma a'a'' = 0.$$

Similarly, if $x = 0$, $z = 0$ be the second axis, we have

$$E_1 + \theta_1 E_1' + f_1 E_1'' = 0,$$

with

$$\Sigma a_1 a_1' = 0, \qquad \Sigma a_1 a_1'' = 0, \qquad \Sigma a_1 a_1'' = 0.$$

Moreover, every complex of the first system must be in involution with every complex of the second. These results show that the invariant of one of the complexes of each system vanishes. Since the discriminant of a series is invariant under linear transformation of the hexaspherical coördinates, surfaces having only plane lines of curvature can not be transformed into general surfaces having spherical lines of curvature by inversion in a linear complex. This configuration is treated in my dissertation, § 18, III, 1 β, page 45. The cyclide becomes a quadrilateral inscribed in the absolute circle at infinity.

CORNELL UNIVERSITY,
April, 1904.

ADDITION TO A THEOREM DUE TO FROBENIUS.

BY PROFESSOR G. A. MILLER.

(Read before the San Francisco Section of the American Mathematical Society, April 30, 1904.)

IN a paper presented by the writer at a recent meeting of the London mathematical society it is proved that the number of cyclic subgroups of order p^s, p being any odd prime and $s > 1$, which are contained in a non-cyclic group of order p^m is always a multiple of p. From this theorem it follows directly that the number of cyclic subgroups of order p^s in any group G must be a multiple of p whenever the Sylow subgroups of order p^m are non-cyclic. When these Sylow subgroups are cyclic the number of the cyclic subgroups of order p^s contained in G is clearly of the form $1 + kp$. In all other cases G contains $1 + kp$ non-cyclic subgroups of order p^s. In other words, if G

contains one non-cyclic subgroup of order p^s it must contain $1 + kp$ non-cyclic subgroups of this order.

Frobenius has recently proved that the number of operators of G which satisfy the equation $x^n = s_1$ is a multiple of n whenever s_1 is an invariant operator of G.* Since a cyclic group of order p^s has $p^{s-1}(p-1)$ distinct generators the results of the preceding paragraph prove that the number of operators of G which satisfy the equation $x^{p^s} = 1$ without also satisfying the equation $x^{p^{s-1}} = 1$ is a multiple of p^s whenever the Sylow subgroups of order p^m in G are non-cyclic. In this case G *must contain a multiple of* $p^{s'+1}$ *operators which satisfy the equation* $x^{p^{s'}} = 1$, $0 < s' < m$, since the number of its operators which satisfy this equation without also satisfying $x^{p^{s'-1}} = 1$, increased by those which satisfy the latter equation, is a multiple of $p^{s'}$.

We proceed to prove that *the number of operators of order* $n = p^s m_1$, m_1 *being prime to* p, *is always a multiple of* p^s, *whenever the Sylow subgroups of order* p^m *in* G *are non-cyclic.* If one of the prime factors q of n is such that $q - 1$ is divisible by p the theorem requires no proof since the number of the generators of a cyclic group of such an order is a multiple of p^s. When this condition is not satisfied it is only necessary to prove that some Sylow subgroup P_m of order p^m transforms just lp cyclic subgroups of order n into themselves.

If P_m does not transform any cyclic subgroup of order n into itself the theorem requires no proof. If it transforms such a subgroup into itself, all the operators of P_m must be commutative with each of the operators of this subgroup whose order is prime to p. Hence G contains the direct product of P_m and the group generated by these operators. This direct product contains a multiple of p cyclic subgroups of order n since P_m contains a multiple of p cyclic subgroups of order p^s. If G contains another cyclic subgroup of order n which is transformed into itself by P_m, it must contain another such direct product, etc. As the cyclic subgroups of order n in these direct products are distinct, the theorem is proved. Just as in the second paragraph, it may be observed that the number of operators of G which satisfy $x^n = 1$ is a multiple of p^{s+1}, $s < m$.

STANFORD UNIVERSITY,
April, 1904.

* Frobenius, *Berliner Sitzungsberichte*, 1903, p. 895.

ON SELF-DUAL SCROLLS.

BY PROFESSOR E. J. WILCZYNSKI.

In a paper, published in the BULLETIN for June, 1904, page 440, Mr. C. H. Sisam gives a proof for a theorem previously enunciated and proved by me in the *Mathematische Annalen*, volume 58, page 256.

Unfortunately, however, he follows me in giving an inexact formulation of the theorem in question. I have used the word *self-dual* in a more restricted sense than is usual, without having properly called attention to the fact. As others may be misled also, a few words of explanation seem to be in order.

A dualistic transformation may have the property of converting a ruled surface into itself *without interchanging its generators*, so that every generator of the surface is transformed into itself. It is merely of scrolls, for which such a transformation exists, that I wish to assert the theorem that they belong to a non-special linear complex. It is only to this case that Mr. Sisam's demonstration applies.

There actually exist ruled surfaces, self-dual in the general sense, which do not belong to a linear complex. The following example of such surfaces is due to Professor Corrado Segre, who first called my attention to the fact that my theorem was badly formulated.

Consider any dualistic transformation R, together with its various powers R^2, R^3, etc. A line g will be transformed successively into g_1, g_2, etc. It is possible to make g move in such a way, that $g, g_1, g_2, \cdots$ will describe the same scroll, which will obviously be self-dual without belonging necessarily to a linear complex. In this case however, the generators of the surface are interchanged.

CAMBRIDGE, ENGLAND,
June 29, 1904.

THE OPPORTUNITIES FOR MATHEMATICAL STUDY IN ITALY.

THE question where a young mathematician shall complete his studies is one of ever recurring interest. We are in the habit of referring to Emerson's $\Phi B K$ address as the "Intellectual declaration of independence of America" and we rejoice to feel that with those memorable words we threw off our yoke of bondage to the Old World. On further reflection, however, we admit that Pasteur's epigram may be inverted; that if a man of science has a fatherland, science itself knows none, and the wise student will always, like Mahomet, go to the mountain. He will complete his education in that country, and at that university where, for his special needs, the best subjects are best taught.

American students of mathematics, who intend to devote their lives to the subject, have generally in the past deemed it wise to spend more or less time at a European university, and though we may point with pride to the work that is being done to-day in our own graduate schools, it is safe to predict that for a long time to come, this migration will continue. Now to most Americans the words "study in Europe" and "study in Germany" are synonymous, and the reasons for this are not far to seek. The prestige of the German universities, their well deserved renown for free research and profound scholarship, and the scientific standing of those who teach there, have been, and will continue to be, the determining motives leading our students to the German Empire. And yet the whole truth has not been told when we have merely praised the German universities. Other universities have come forward in the last decades; Germany has no "corner" in science nor yet in the pursuit of scholarship, and to believe so is a sign of a sad, if all too common, intellectual provincialism. Moreover it is a highly debatable point whether our own American mathematical scholarship has not had a full measure of German influence, and whether the time is not come when we should show ourselves more ready to assimilate ideals from other lands. We should, I am sure, be no losers by having among us more teachers and students who had frequented the other European universities, nor

would such persons look upon themselves as having enjoyed only the second best in education. Yet at this point we are confronted with a difficulty, for, compared with Germany, the conditions of life and study elsewhere in Europe are imperfectly known and understood in America. Hence Professor Pierpont's article upon "The teaching of mathematics in France" * was most opportune, and in a similar spirit I wish to give some account of opportunities for mathematical study which an American will find in Italy. I will preface what I have to say with the remark that I have had the privilege of attending only one Italian university, Turin; but as all the universities are under the immediate control and supervision of the State, and the broad outline of the course of instruction is prescribed by law, the same for all, what I have to say should apply with but slight modification to every university in the peninsula.

The American students who attend a European university may be divided into two classes, those who are seeking a doctorate, and those who have come to study merely a particular subject, or to hear a particular professor. It is my wish to show that for the former class of students the Italian universities are, as at present constituted, ill adapted, but the latter class might frequent them to great advantage.

The prescribed mathematical course in the Italian universities presents a certain superficial resemblance to that which is followed at Oxford and Cambridge. The period of residence is four years, and that term is marked by two great series of examinations. The first examinations, which are divided between the first and second years, lead to the "licentiate" or licence to teach in the lower schools. The final examinations lead to the "laureate" and confer the title of "doctor." They constitute the test required of all who wish to teach in gymnasia. A student is not admitted as a candidate for the laureate until he has passed the licentiate.

The requirements for the licentiate are the same for those who wish to pursue mathematics, physics, or engineering. After presenting proof that he has received a good school education, the candidate is required to attend the following courses:

1. Experimental physics for two years.
2. Inorganic and organic chemistry.
3. Algebraic analysis.

* BULLETIN, 1899.

4. Infinitesimal analysis.
5. Mineralogy.
6. Analytic geometry.
7. Projective geometry with design.
8. Descriptive geometry with design.

As American graduate students are scarcely likely to follow these courses, we may pass over them with no further comment than to point out the particular emphasis laid on the general subject of geometry.

A candidate for the laureate is allowed a certain freedom in the choice of subjects he will follow. He is required to follow the course in rational mechanics, and beside that, four courses chosen from these six:

1. Theoretical geodesy.
2. Mathematical physics.
3. Higher analysis.
4. Higher geometry.
5. Higher mechanics.
6. Astronomy.

The last course (astromony) is not given in all universities.

In some of the subjects, besides the lectures, there are recitations with problems, like the "travaux prâtiques" at the Sorbonne, presided over by an assistant. The student generally offers himself for examination in at least three of his five courses at the end of his first year of candidacy; his second year is largely occupied with his dissertation, and the preparation of his minor theses.

It must be confessed that, to an American eye, this list of subjects is somewhat strange. It is not likely that many students will care to earn the title of "dottore" in mathematics without studying either higher analysis or higher geometry, but they are at liberty to do so. If the professor of higher analysis happens to be lecturing of the theory of forms, the student may go forth with only a rudimentary knowledge of differential equations; if the subject be elliptic integrals, he probably will have little more than a bowing acquaintance with invariants. Most surprising of all is the placing of theoretical geodesy on a plane with the other subjects.

The examinations are all oral, and cover only the material discussed in the course of lectures delivered that year. There are many grades of laureate, and the student who has read nothing but what was suggested in lecture is not likely to pass out with "full wishes and praise" as the highest grade is called, nor will the most favorable opportunities probably be waiting for him in future; still he has the highest degree which the university confers.

The dissertations, as is natural, present great variation in value and originality. The candidate is required to publish a full résumé of his results, but not the thesis itself; whereby a long suffering mathematical public is spared much, for the feebler dissertations never see the light. The better ones find ready acceptance by the mathematical journals, or are laid before learned societies, and need not fear comparison with the work of aspirants for the German Ph.D. The preparation of the minor theses is much less of an affair, and usually occupies the candidate but a few weeks. No great originality is expected; he is merely called upon ordinarily to make a comparative study of various expositions of the assigned topics, and master those which he prefers.

It will be seen, I think, that the Italian laureate will not attract many American students as a substitute for the Ph.D. Few would care to devote time to mastering, not the five subjects, with which they may be more or less familiar, but the presentation of those subjects which had been given at that university. Fewer still would care to begin their course by offering themselves for examination in the diversified subjects of the licentiate.

These difficulties disappear in the case of the student who comes for a shorter time, say a semester, or a year, to study a particular subject with a particular professor. The requirements for such studies are libraries, lectures, and personal help. Where are they best supplied? In England the lectures suffer from the fact that they are purely utilitarian, means to prepare students for the great examinations. In Paris the Bibliothèque nationale is difficult of access; the library of the Sorbonne is overcrowded, and open only a limited number of hours every day; the smaller libraries, like that at the Ecole Normale, are ill supplied with funds. Moreover, in Paris the personal element is notoriously lacking. This difficulty exists in some measure also at the larger German universities, owing to the larger number of those wishing to be helped; in the smaller ones, the choice of lectures is naturally somewhat restricted, nor is it easy to find in Germany any lectures exhibiting the charm and finish of those delivered by the great French teachers.

In the better Italian universities, these three desiderata seem to be very happily combined. In Turin there is an excellent mathematical library, opened twice daily, from which with the

professor's permission students may withdraw what books they will. The large national library is in the university building, and is open all day to whoever wishes to enter. Lastly, the privilege is sometimes granted of using the fine library of the Royal academy of science, a delightful place, which rejoices especially in possessing the proceedings of all imaginable learned societies. I doubt whether anything corresponding to this last collection could be found in those universities which are in the smaller cities; duplicates of the two former would certainly exist in any of the larger Italian universities.

The general plan of lectures, as outlined above, is determined by the State. At the same time such headings as "Higher analysis," "Higher geometry" are so comprehensive as to leave to the teacher the greatest discretion in the choice of material. Some fortunate professors give a new course each year, others run through a cycle including a greater or less number of subjects. Americans are sure to find lectures on subjects that will interest them, and they will have the French, rather than the German standard of clearness and elegance. They will also be struck by the eclecticism of the instructor, for Italian mathematicians read widely. I remember being impressed at the beginning of one course of lectures by the fact that the professor put down, as principal works of reference, books in four different languages, and remarked that those of his hearers who could not read English, French and German, must certainly make up the deficiency in the course of the year.

The pleasantest feature of the life of an advanced student in Italy will be the personal contact with that professor in whose subject he is specially interested. Seminars do not exist, nor have I seen traces of students' mathematical clubs, but the relation between teacher and pupil is most direct and most helpful. The professor expects to give help and advice to those students who are preparing dissertations upon his subject, and these he will cordially extend to any student pursuing a similar line of work.

The principal difficulties which an American encounters at an Italian university are of a formal sort. Should he wish merely to come to lectures as a guest of the professor, he will be more than welcome. Should he feel that he had no right to accept so much without enrolling himself and paying the usual fees, he will need some patience to fulfill all the formalities.

We ordinarily suppose that the English universities stand in a class by themselves in the matter of ill-contrived machinery, and that their regulations are the most hampering, but this is a mistake. True it is that an American who studies at Oxford must wear academic dress at the proper times and seasons, and must forego the dangerous habit of carrying weapons such as javelins, while at Cambridge he will not be allowed to play marbles on the steps of the Senate House. In larger matters the regulations are elastic and reasonable. In Italy, however, the statutes are planned for one type of student wishing one thing, and when a student presents himself who wants something else the process of adjustment is difficult and jarring.

There are three ways in which an American may enter an Italian university. To begin with, he may lay aside his dignity, and enter the first year. The difficulty here is that he must show a certificate of a good school education, with a written declaration that in America such a certificate would qualify for admission to a university. This certificate must be countersigned by an Italian consul in America. Secondly he may enter for one of the later years. Here the school certificate is to be replaced by documentary evidence that he has received instruction equivalent to that given in the years passed over in Italy. This also requires the consular signature. In addition, as the student has not migrated from another Italian university, he must begin by paying all the dues for those years which he has omitted. It is doubtful whether this method will ever be popular among Americans. The third way is to register as an "auditor." The formalities which must be fulfilled here, and which will be explained step by step, are the following:

1. Apply for registration on a prepared form and copy the application on a piece of stamped paper (to be bought at any tobacconist's), taking care not to run over into the margin.

2. Pay at the sub-treasury twelve lire (say $2.40) per course of lectures per semester.

3. Pay to the university bursar ten lire for "eventual damage" to the plant, and three lire fifty for a matriculation book.

4. Deposit the receipts for these sums at the proper office, together with two copies of the candidate's photograph, of the official size and shape. For these special arrangements are made with certain photographers.

5. Deposit a birth certificate countersigned either by an Ital-

ian consul in America or some personage recognized by the authorities. The student will be allowed to attend lectures from the beginning, and need not wait until he has completed all the requirements.

The birth certificate requirement always appears strange to an American. I was told that it was most important as a means of verifying the truth of my declaration concerning my age. I have never been able to find out what should happen in the case a candidate appeared declaring that such a thing was unprocurable. Probably this possibility has never occurred to any one. I remember hearing from an American who had been at the Ecole normale at Paris that there also they had demanded a birth certificate, and when he said that he had none, they were pained, not so much by his failure to produce the document, as by his obvious untruthfulness in saying that he did not have it. I am very sure that an American who could honestly say that a certificate of his birth was non-existent would not be refused registration on that account, though how the matter would be settled I do not know.

The further requirement of countersigning this precious document is, at first sight, exasperating. In my own case I heard not a word of it until I had received the certificate sent out at my request from America. I appealed for a dispensation, first to the Rector, and then through the American ambassador to the Minister of public instruction, but was refused. In the end I sent the certificate to Rome, where our embassy took charge of the formalities, and this might be the easiest way for Americans to follow in the future.

The Italian scholastic year is blessed with many holidays. The long vacation practically extends from the middle of June to the first of November. Christmas and Easter each provide ten days of vacation, while the carnival furnishes another week. Then there are six religious, and five national holidays. Lastly there are unannounced holidays. At periods of political excitement the students have a patriotic custom of marching about in bands, invading the lecture rooms, and calling on the professors for speeches. Should the doors be locked they will applaud enthusiastically thereon with hands and feet. As there is no discipline to deal with these cases, and it is not etiquette to introduce the police, the authorities frequently adopt the prudent course of closing the university until word arrives that the students are ready to return to ordinary academic ways.

Another picturesque custom prevails in some of the larger courses. If the professor be late in coming to lecture, the students indulge in a pandemonium of assorted noises till he arrives. This seems to discourage the adoption of the "Academisches Viertel." It is in ways like these that the students betray what is traditionally called a spirit of youth and gaiety suitable to their age (say eighteen to twenty-two) and in strong contrast to a certain, unmistakable intellectual maturity. This latter is striking. At the beginning of the present year I had the pleasure of hearing the truly remarkable opening address delivered by Professor Pio Foa. The subject was the necessary correlation in education of the speculative and experimental sciences, and from the first word the discussion was maintained at an intellectual level adapted to the most scholarly audience. The day was warm, the hall ill-ventilated, and that part of it reserved for students was without seats. There they stood, jammed together for an hour, giving perfect attention. At the close they applauded the speaker warmly, crowding enthusiastically about him as he left the hall.

About the social life of Italian students I know little. In Turin there is a large body called "The students association" which has some rooms, and a chapter of the international society "Corda Fratres," which publishes a magazine and rejoices in many officers. There is also a students' fencing club. Anything like the corporate life of an English college or a German "Verbindung" seems entirely lacking.

The cost of living in Italy is low according to American standards, although I should judge a little higher than what a student would pay in some parts of Germany. Furnished rooms are easy to find, as is also "pension de famille." In Turin the number of resident foreigners is almost a negligible quantity, compared to the crowds who go to other cities. Hence the tourist fares worse than elsewhere, but it is easier to enter into the life of the people, and the student should always try to associate with the native rather than the foreign population.

The question of language should not deter any one from coming to Italy to study, for if Italian is a bad language to speak easily, it is an easy language to speak badly. A student who should give a fair amount of time to studying any one of the many "methods" for learning the language during the summer vacation preceding his residence, and spend the last

month of that time, October, studying in Italy, will not be an accomplished Italian scholar, but he will have no trouble in understanding lectures, and in living comfortably in an Italian community.

There is, lastly, the question of the vacations. It is neither necessary nor suitable to dwell here upon the inestimable advantage to a student of spending his vacations in Italy, taking little journeys hither and thither. The serious student will choose his university by what it offers him in term time, not by what he can get out of term. Yet he who decides to come to Italy will realize that he will have the chance, with little trouble and small expense, to add to his special work a wider culture which no amount of mathematical study can give him, nor yet entirely destroy.

J. L. COOLIDGE.

TURIN,
March, 1904.

VECTOR ANALYSIS.

Vectors and Rotors, with Applications. By O. HENRICI and G. TURNER. London, Edwin Arnold, 1903. xv + 204 pp.

Introduction to Quaternions. By KELLAND and TAIT. *Third Edition*, by C. G. KNOTT. London, Macmillan and Co., 1904. xvii + 208 pp.

Vektordifferentiation und Vektorintegration. Von V. FISCHER. Leipzig, J. A. Barth, 1904. iv + 82 pp.

THE first years of this century have seen an interest in vectors and related subjects, such as has never before been observed. This may be due somewhat to the activity and broad spirit of the International association for the promotion of the study of quaternions and allied systems of mathematics; but more probably it is caused by the increasing desire of physicists for a notation which will represent more briefly and more concretely the three dimensional quantities with which they are forced to deal. With this demand on their part the champions of the various systems come forward to press upon us the advantages of their particular system and especially the disadvantages of all others. Felix Klein is at the head of a commission to investigate the relative merits of different methods, and a number of articles in the recent

issues of the *Jahresbericht der Deutschen Mathematiker-Vereinigung* indicates that the commission is not failing to secure plenty of advice. It only is to be feared that the commission may attempt to enact a rigid code. That would be unfortunate and certainly futile. No theorizing can determine which of the many systems shall be adopted. Usage is the only judge. It may be hoped that the commission and its advisers will turn their efforts not to saying what shall be used, but to using that which seems to them individually to be preferable. Then usage cannot fail to decide. And we may prophesy that the decision will be for one system in one place and another in another. There is a deal of sense in Heaviside's remark that for the study of quaternions, quaternions is undoubtedly the best instrument. The fact is that all these methods are but special multiple algebras, and when once one becomes accustomed to use multiple algebra he uses that one which best suits his immediate convenience. In this connection may be quoted the broad-minded, farsighted words with which Gibbs closed his vice-presidential address to the meeting of the American association for the advancement of science at Buffalo in 1886. He said: "But I do not so much desire to call your attention to the diversity of the applications of multiple algebra, as to the simplicity and unity of its principles. The student of multiple algebra suddenly finds himself freed from various restrictions to which he has been accustomed. To many, doubtless, this liberty seems like an invitation to license. Here is a boundless field in which caprice may riot. It is not strange if some look with distrust for the result of the experiment. But the farther we advance, the more evident it becomes that this too is a realm subject to law. The more we study the subject, the more we find all that is useful and beautiful attaching itself to a few central principles. We begin by studying *multiple algebras:* we end, I think, by studying MULTIPLE ALGEBRA." Pity it is that this great philosopher of algebra, sole and true successor to Grassmann, did not live to print his later reflections! Pity it is, too, that of the large number of zealots in this field so few have reached Gibbs's first stage, so many study but a single multiple algebra! In this narrowness lies most of the cause of strife between the parties.

We have at present before us three books, each with its individual merits, each written from a different standpoint. Professor Henrici teaches in City and Guilds of London Central Tech-

nical College. His students come to him direct from school; for all one can see they know little if any trigonometry. The problem of the teacher is to start their preparation in technical mechanics. Henrici finds vectors the instrument best suited for the purpose. In fact he urges the introduction of the subject into schools to accompany instruction in geometry. Of the book in question the first 48 pages are given to a detailed account of the addition and subtraction of vectors and their multiplication by a scalar. The text is amply illustrated by examples from geometry and statics of a point. The problems proposed for the student are numerous and excellent here as throughout the book. An extended treatment of centers of mass, including the graphical method of finding the center of mass by the aid of the link polygon, forms the second chapter. As an introduction to elementary work in engineering it is admirable. The following chapter takes up the scalar and vector products of vectors. Henrici distinguishes the sort of product by the kind of parentheses used. $(\alpha\beta)$ is the scalar product; $[\alpha\beta]$ the vector. Rotors, treated first as geometrical objects, second as forces applied to a rigid body, are taken up in the fourth chapter. The rotor is defined as a localized vector free to move along its own direction. It is shown that although numerous are the differences between rotors and vectors, yet great is the advantage of using the notations of vectors in treating rotors. The link polygon is constantly employed in connection with the evaluation of resultant rotors and movements. The theory of the loaded beam and of the bending movement is also touched upon. In the sixth chapter we continue the foregoing by applying the theory to stresses in frames. The reciprocal relations between the frame and the stress diagram are fully brought out. Thus these two chapters form a complete introduction to graphical statics. The exercises are for the most part to be solved by means of the drawing board. We should certainly congratulate the students who have the good fortune to begin their technical training with so broad, thorough, and yet so simple a treatment of vectorial and graphical methods.

It has long been admitted that, everything considered, the best introduction to quaternions is Kelland and Tait's. Tait's own treatise is too stiff and unyielding toward the reader. Hamilton's, though easier, is long, and until recently it has been difficult to obtain. If any book has popularized or is to pop-

ularize quaternions it is this one under review. Without attempting to speculate concerning the possible future use of quaternions to physicists, we may well agree that, physicist or no physicist, quaternions eminently deserves to be studied for its own sake. For this purpose Kelland and Tait's Introduction is admirably suited — owing doubtless to the extraordinary teaching ability of Kelland. In preparing the third edition Professor Knott has exercised a wise conservatism toward the greater part of the text. He has, however, introduced a great improvement in chapters 3 and 4 by bringing out clearly the true standpoint and the logical development of the Hamilton system. This will be of service to one who is trying to get into the spirit of the algebra. Another valuable change is the greater attention paid to the dynamical and physical applications. Although nothing can really supplant Tait's chapter on this subject in his treatise, the ordinary student of physics will now find Professor Knott's ninth chapter about sufficient to his greatest needs. The only change we could suggest in the work is that the editor keep right on a little further and replace some of the more extended applications to geometry by a treatment of some physical problems such as systems of forces, the geometry of strains, and the propagation of light in crystalline media. But we recognize the delicacy one feels in recasting the work of others and may well be content with what Professor Knott has already accomplished.

Dr. Fischer's work is in no sense a text-book. It is in reality an original monograph serving to develop the ideas of Gibbs. The author thinks, and with considerable right, that space differentiation which is usually represented by ∇ might with better analogy be represented by $d/d\mathbf{r}$. As this idea depends on division, we define the reciprocal of $\mathbf{a}$ to be $\mathbf{a}/a^2$, and $\mathbf{a}/\mathbf{b}$ to be the product of $\mathbf{a}$ into the reciprocal of $\mathbf{b}$. If then V is a scalar function of position in space, $d\,V/d\mathbf{r} = \nabla V$. This is a vector quantity. The derivative of a vector function V is a linear vector function, that is, a dyadic. The scalar and vector of this dyadic, $(d\mathbf{V}/d\mathbf{r})_s$ and $(d\mathbf{V}/d\mathbf{r})_\times$ according to the notations of Gibbs, are respectively the divergence and curl of $\mathbf{V}$. These the author represents by $d\bullet\mathbf{V}/d\mathbf{r}$ and $d\times\mathbf{V}/d\mathbf{r}$. The work in the text is developed with great care and with ample geometric illustration. It is well worth reading by all who are interested in vector analysis and especially by those who are acquainted with the methods of Gibbs. One may note that in

a pamphlet on Vector Analysis printed in 1884, but not published, Gibbs suggested as possible and perhaps preferable the notation d/dr in place of ∇. This idea he never developed, at least so far as is known, and consequently Dr. Fischer's monograph fills an evident gap in the theory.

E. B. WILSON.

CAMBRIDGE, MASS.,
June 23, 1904.

THE MATHEMATICS OF INSURANCE.

Versicherungsmathematik. Von ALFRED LOEWY. Leipzig, Sammlung Göschen, 1903. 145 pp.

IN publishing this book the "Sammlung Göschen" has certainly followed out successfully its expressed policy of giving to the public a brief, yet clear and up-to-date development of one of the most interesting applications of mathematical theory. While a reader who is unacquainted with the subject of life insurance would find Professor Loewy's exposition somewhat too condensed, anyone with a knowledge of elementary algebra who has some acquaintance with the business aspect of the subject cannot fail to appreciate the value of this little pocket edition which contains in its 145 pages the development of all the important formulæ needed by the actuary.

While one recognizes at once the meanings of many of the words such as Nettoprämie = net premium, Sterblichkeitstafel = mortality table, the significance of some of the German expressions, of which a glossary of 15 follows, is not at all evident. Indeed, a few are not to be found in the average German-English dictionary and their meaning can only be learned from the context.

Zinsfuss = rate of interest,
Zinseszins = compound interest,
Barwert = present value,
Leibrente = annuity,
Erlebensversicherung = endowment,
postnumerando = payable subsequently,
pränumerando = payable in advance,
Rückversicherung = reinsurance,
Bruttoprämie = gross premium,
Prämienrückgewähr = return (of part or whole) of premium,
Rückkaufpreis = surrender value,
Passiva = liabilities,
Aktiva = assets.

Karenzzeit = period of deferred insurance (a policy payable at death, provided death is not within m years, is spoken of as a policy with m-jähriger Karenzzeit).

Zillmersche Prämienreserve [zillmern (verb)] = reserves calculated according to the formula

$$ {}_{m}V'_{x} = \left(P_{(m)} - P_{x} - \frac{\delta_{x}}{\mathbf{a}}\right)\mathbf{a}_{(m)}, $$

where ${}_{m}V'_{x}$ is the reserve on the sum 1 after m years, the insured being of age x at the time the policy is written; $P_{(m)}$ = net yearly premium on the sum 1 which an individual, age x, would have to pay, the term of payments being that which remains for the individual of age $x + m$; P_{x} = net yearly premium beginning at age x and for the sum 1; $\mathbf{a}$ = the present value of a life annuity of sum 1 payable at once; $\mathbf{a}_{(m)}$ bears the relation to $\mathbf{a}$ that $P_{(m)}$ does to P_{x}.

Every time a conventional symbol is introduced its number (Roman) is printed in the margin, thus enabling the reader to find easily the meaning of the symbols in any formula under consideration. As might be expected, the notation is not that of the Actuarial Society of America; the author follows, with some exceptions, the universal standard notation of the International Congress of Actuaries of 1895.

The symbol m_{x} is ordinarily used to express the "central death rate" $d_{x}/l_{x+\frac{1}{2}}$; in the present work m_{x} denotes the number of deaths out of $A_{x} + B_{x} - C_{x}$ individuals where A_{x} is the number, age x, under observation, B_{x} the number (of the same age) which is added during the year, C_{x} the number which is lost track of during the year.

Unlike the English writers, the Germans give special names to the present value of the unit sum $V = 1/(1 + i)$ (i = rate of interest), and to the expression $C_{x} = d_{x}v^{x+1}$; the former is called the "Diskontierungsor Abzinsungsfaktor," the latter the "Zahl der diskontierten Toten des Alters x."

The fallacy involved in assessment life insurance is now well understood and Loewy therefore dismisses this subject with a brief and unfavorable mention.

On page 92 it is stated that a well known German company computes the gross premium A'_{x} of a one payment life policy by means of the formula $A'_{x} = \frac{11}{10}A_{x}$ where A_{x} = net premium. In America the "loading" is higher than this, but on the other hand policies are "participating" and draw dividends.

In the case of entire life policies, yearly payments, the formula is $P_x' = 1.24\ P_x$ for ages exceeding 34 years, making a loading of 24 %. In America the loading is sometimes less and sometimes more than this, varying with the different companies. For non-participating policies it is much less. It is not calculated as a percentage of the net premium however.

In the case of half yearly payments, the Germans add one per cent of yearly net premium; in case of quarterly payments two per cent is added.

The American law requires an insurance company to have on hand at the end of the first year, when the expenses are heaviest, the full reserve according to a mortality table in which no account is taken of the gain due to selection by medical examination. The large and wealthy companies meet this requirement by a bookkeeping device, transferring from the surplus to the first year's reserve enough to meet the legal requirements. The smaller companies are compelled, however, to resort to the following plan. If the contract is for a twenty payment life policy, they issue a one year term policy, the regular insurance commencing one year later and extending over nineteen years. Actuaries are divided in opinion at present on the moral point involved in this device; although unjust from the technical point of view it is difficult to see how a new company could come into existence in any other way.

The German law it more flexible, allowing the company to draw upon the first year's reserve, for expenses, to the extent of 12.5 M. per thousand marks of insurance.

Experience shows that the Gompertz-Makeham formula gives the most satisfactory way of graduating mortality tables and it is the method in general use at the present time. For this reason the reviewer regards the author's treatment as too brief and condensed. The mere statement of the final result in the integrated form with the specification of the value of the constants is not sufficient for one who is reading it for the first time.

This fundamental formula may be developed in an elementary way as follows. Suppose that those who die between the ages x and $x + 1$ are immediately replaced by other individuals of the same age. The number of deaths during the year under these circumstances, divided by the number l_x who enter upon this year, is called the "force of mortality" μ_x, — in the language of the calculus

$$\mu_x = -\frac{1}{l_x}\frac{dl_x}{dx} = -\frac{d\log l_x}{dx}.$$

According to the Institute of Actuaries textbook

$$\mu_x = \frac{d_{x-1} + d_x}{2\,l_x} = \frac{l_{x-1} - l_{x+1}}{2\,l_x}$$

very closely. μ_x can be found from the census statistics (which give the central death rate m_x) by means of the relation $m_x = \mu_{x+1/2}$.

In 1825 Benjamin Gompertz proposed the formula $\mu_x = Bc^x$ on the assumption that with increasing age there is an inability, increasing in geometric progression, to withstand destruction. Now death may also be due to chance without previous deterioration. Taking this into account Makeham, in 1860, gave the modified formula $\mu_x = A + Bc^x$. From this it follows that $-d\log l_x/dx = A + Bc^x$. Integrating, and putting $-A = \log s$, $-B/\log c = \log g$, there results $l_x = k\,s^x g^{c^x}$ where $\log k$ is the constant of integration. The values of the constants differ according to the mortality tables from which they are determined. Thus, Loewy gives $\log s = -0.002527627$, while the Institute of Actuaries text-book gives $\log s = -0.002689327$.

A very interesting feature of the book is the insight given by it into the conditions of German life which help one to understand why deferred temporary annuities and endowments are more popular in Germany than in America. The former are often purchased for the purpose of defraying the expenses of a son at the university. The latter, besides being a provision for old age, are also purchased for the purpose of providing a daughter with her "Aussteuer" and a son with the expenses of the one year of military service. According to the German law those who complete the "Unter-sekunda" and are willing to defray their own expenses are exempted from one of the required two years of service in the infantry.

The book seems to be free from misprints and other errors. By careful condensation the author has reduced it to pocket size. It will be found a very useful little handbook.

SAUL EPSTEEN.

SHORTER NOTICE.

Lehrbuch der Differenzenrechnung. Von D. SELIWANOFF. Leipzig, B. G. Teubner, 1903. 92 pp.

AT the request of the well-known Leipzig publisher, B. G. Teubner, the author has elaborated his article on finite differences in the Encyklopädie der Mathematischen Wissenschaften, volume 1, pages 918–937, to the dimensions of a book. Thus, while the encyclopædia gives but one page to the approximate evaluation of definite integrals and four pages to the subject of difference equations, the book devotes six pages to the former and twenty-nine pages to the latter. The gain in lucidity over the encyclopædia article is therefore considerable, and, indeed, although the author omits certain questions which might well be taken up, those that he does treat are presented in a delightfully clear and simple manner.

The books of Boole and Markoff are more complete, but this work of Seliwanoff should be regarded, not as a handbook for one who is familiar with the subject, but as a textbook for the beginner who desires to learn the theory and technique of computation, such as the methods of interpolation, constructing tables, estimation of unavoidable errors.

Part I devotes thirty-two pages to the subject of differences. After developing some of the most important general theorems in chapter 1, the question of interpolation is taken up in chapter 2, where the author considers exact and approximate interpolation, computation of the roots of numerical equations, and the computation of logarithms and antilogarithms. The methods of evaluation of definite integrals in chapter 3 are all elementary, culminating with Simpson's formula.

In Part II, chapter 1 treats the subject of indefinite and definite summation. According to the conventional usage, the symbol $\sum$ is employed as the calculus analogue of the sign of integration $\int$. In the opinion of the reviewer the symbol S would serve the purpose somewhat better. First, the use of the letter $\sum$ as a functional symbol where the (finite) integration is not possible is a departure from its recognized significance in various domains of analysis and consequently a little confusing; second, the letter S corresponds closer to the long s of the integral calculus; and third, the $\sum$ would re-

main available to indicate a summation of integrals. Chapter 2 develops in an elementary manner the Jakob Bernoulli function

$$\phi_n(x) = \sum_0^x \frac{x^{n-1}}{(n-1)!}$$

and some of its properties. Chapters 3, 4 are devoted to the Euler formula

$$F(a) = \frac{1}{h}\int_a^{a+h} F(u)du + A_1[F(a+h) - F(a)] + A_2 h^2 F''(a+\theta h)$$

and to some of its important applications, such as the development of Stirling's formula

$$\log(1\cdot 2\cdot 3\cdots x) = \log\sqrt{2\pi} + (x+\tfrac{1}{2})\log x - x - A_2\frac{1}{x} + A_4\frac{2!}{x^3} + \cdots.$$

Part III takes up the subject of difference equations. In chapter 1 the general equation $y_{x+n} = f(x, y_x, y_{x+1}, \cdots, y_{x+n-1})$ and the linear equation $y_{x+n} + p_1 y_{x+n-1} + \cdots + p_n y_x = Q_x$ are discussed very briefly. The second chapter is devoted to the linear equation of the first order and to the interesting application of expanding $\cos xt$ according to powers of $\cos t$. Chapter 3 treats in somewhat greater detail the linear difference equation with constant coefficients.

Although many questions of interest from the theoretical standpoint as well as from that of the higher applications are not touched upon, we are indebted to the author for an excellent elementary textbook on a fascinating and important subject.

SAUL EPSTEEN.

NOTES.

THE San Francisco Section of the AMERICAN MATHEMATICAL SOCIETY held its fall meeting at the University of California, on Saturday, October 1. The preliminary programme included a conference on recent investigations in the foundations of geometry.

THE General Index of the first thirteen volumes of the BULLETIN, 1891–1904, compiled by Dr. EMILIE N. MARTIN, is now in press. The book, of eighty pages, contains an index by authors, index of works reviewed, an elaborate subject index, and an index of authors of papers read before the Society since 1891.

THE July number (volume 5, number 3) of the *Transactions* of the AMERICAN MATHEMATICAL SOCIETY contains: "The convergence of algebraic continued fractions whose coefficients have limiting values," by E. B. VAN VLECK; "The Sylow subgroups of the symmetric group," by W. FINDLAY; "On the smaller perturbations of the lunar arguments," by E. W. BROWN; "Sets of independent postulates for the algebra of logic," by E. V. HUNTINGTON; "On the order of linear homogeneous groups (second paper)," by H. F. BLICHFELDT; "Algebras defined by finite groups," by J. B. SHAW; "A system of axioms for geometry," by O. VEBLEN.

THE July number (volume 26, number 3) of the *American Journal of Mathematics* contains: "Bemerkungen zu Herrn D. N. Lehmer's Abhandlung in Bd. 22 dieses Journals, S. 293–335," by E. LANDAU; "On hypercomplex number systems in seven units," by H. E. HAWKES; "Memoir on abelian transformations," by L. E. DICKSON.

THE concluding (July) number of volume 5 of the *Annals of Mathematics* contains: "Some elementary theorems concerning the steady flow of electricity in solid conductors," by B. O. PEIRCE; "On a linear transformation and some systems of hypocycloids," by R. E. ALLARDICE; "On the integral divisors of $a^n - b^n$," by G. D. BIRKHOFF and H. S. VANDIVER; "Two elementary constructions in complex trigonometry," by A. E. KENNELLY; "Note on Stirling's formula," by S. A. COREY; "Note on Sylow's theorem," by G. A. MILLER;

"The conditions for a plait point," by P. SAUREL; "Acknowledgment," by P. SAUREL.

THE British association for the advancement of science met at Cambridge University on August 17, 1904, the opening address being delivered by prime minister ARTHUR BALFOUR. The president of section A (mathematical and physical sciences) was Professor HORACE LAMB. The papers in this section were devoted almost exclusively to applied mathematics and to physics. The opinion was expressed in prominent quarters that the modern development of pure mathematics was such as to demand a further division of the section in the near future, there being already two subsections, one devoted to physics and the other to astronomy. Among the recipients of the honorary degree of doctor in science from Cambridge University, on the occasion of the meeting, was Major P. A. MACMAHON, one of the general secretaries of the Association. From the field of applied mathematics, Professor VITO VOLTERRA of Rome and Sir DAVID GILL, astronomer royal at Cape Town, were similarly honored. The next meeting of the association will be held at Cape Town in August, 1905, under the presidency of G. H. DARWIN.

AT the meeting of the National educational association at St. Louis on June 28, a mathematical conference was held for the consideration of questions relating to secondary mathematical instruction. At the close of the general meeting, at which several papers were read and discussed, a special meeting of the mathematical teachers of Missouri was held, in response to a circular previously sent out, for the consideration of the advisability of forming an association of the mathematical teachers of the state. It is presumed that a permanent organization will be effected at the time of the next meeting, which will be held at Columbia, Missouri, during the Christmas vacation.

THE annual list of American doctorates published in *Science* presents for the past academic year 281 names, of which 128 are credited to the sciences. The following 13 successful candidates offered mathematics as major subject (the titles of the dissertations are appended): L. D. AMES, Harvard, "An arithmetic treatment of some problems in analysis situs;" C. E. BROOKS, Johns Hopkins, "Orthic curves, or algebraic curves which satisfy Laplace's equation in two dimensions;" W. H. BUSSEY, Chicago, "Generational relations for the abstract group

simply isomorphic with the linear fractional group;" W. B. CARVER, Johns Hopkins, "On the Cayley-Veronese class of configurations;" A. C. LUNN, Chicago, "The differential equations of dynamics;" C. S. FORBES, Columbia, "Geometry of circles orthogonal to a given sphere;" J. N. GATES, Clark, "Cubic and quartic surfaces in four-fold space;" W. A. MANNING, Stanford, "Studies on the class of primitive substitution groups;" C. L. E. MOORE, Cornell, "On the quadratic spherical complex;" VIRGINIA RAGSDALE, Bryn Mawr, "On the arrangement of the real branches of plane algebraic curves;" BURKE SMITH, Yale, "On surfaces which may be deformed with preservation of a conjugate system of curves;" CLARA E. SMITH, Yale, "Representation of an arbitrary function by means of Bessel's functions;" J. W. YOUNG, Cornell, "On the group of sign (0, 3; 2, 4, ∞) and the functions belonging to it." The number of American doctorates in mathematics for each year from 1898 to 1904 is 11, 13, 11, 18, 8, 7, 13.

AN effort is being made to establish a society for the study of the history of the natural and technical sciences. The subject was presented at the third international congress of mathematics at Heidelberg last August, and also at the congress of philosophy (section on the history of sciences) at Geneva in September, and attracted favorable attention. Those who are interested in the founding of such a society are asked to communicate at an early date with Ingenieur F. M. Feldhaus, Rohrbach-Heidelberg, Germany.

THE American universities below offer during the academic year 1904–1905 advanced courses in mathematics as follows:

UNIVERSITY OF MICHIGAN. — By Professor W. W. BEMAN: Solid analytic geometry, first semester, two hours; Differential equations, first semester, three hours; Quaternions, second semester, two hours; Advanced calculus, two hours; Linear differential equations, second semester, two hours. — By Professor A. ZIWET: Projective geometry, three hours; Advanced mechanics, second semester, three hours; Theory of potential, first semester, three hours. — By Professor J. L. MARKLEY: Theory of functions, three hours. — By Professor J. W. GLOVER; Higher algebra, three hours; Theory of annuties and insurance, two hours. — By Dr. A. B. PIERCE: Differential geometry, three hours. — By Mr. E. B. ESCOTT: Theory of numbers, two hours.

STATE UNIVERSITY OF OHIO. — By Professor R. D. BOHANNAN: General theory of functions, three hours; Elliptic functions, two hours. — By Professor K. D. SWARTZEL: Potential function, two hours; Infinite series, two hours. — By Professor H. W. KUHN: Higher plane curves, two hours; Theory of groups, two hours. — By Professor E. F. CODDINGTON: Theory of equations, two hours; Determinants, two hours. — By Professor C. Z. ARNOLD: Differential equations, three hours.

THE various foreign universities below offer during the winter semester of 1904–1905 courses in mathematics as follows:

CAMBRIDGE UNIVERSITY. — *Michaelmas term*, 1904. — By Professor A. R. FORSYTH: Continuous groups, three hours. — By Professor G. H. DARWIN: Figure of the earth and precession, three hours. — By Professor Sir R. S. BALL: Planetary theory, three hours. — By Professor J. LARMOR: Electricity and magnetism, three hours; Mathematical physics II, three hours. — By Professor J. J. THOMSON: Properties of matter, two hours; Electricity and matter, two hours. — By Professor B. HOPKINSON: Applied mathematics, two hours; Electricity, two hours. — By Dr. E. W. HOBSON: Theory of aggregates and theory of functions of a real variable, three hours. — By Dr. H. F. BAKER: Introduction to theory of functions, three hours; Solid geometry, three hours. — By Mr. G. B. MATHEWS: Projective geometry, three hours — By Mr. H. W. RICHMOND: Analytic geometry of curves, three hours. — By Mr. H. M. MACDONALD: Waves (especially of light), three hours. — By Mr. A. N. WHITEHEAD: Symbolic logic and its application to Cantor's theory of aggregates, three hours. — By Mr. A. BERRY: Elliptic functions, Bessel functions and Fourier series, three hours. — By Mr. MONRO: Hydrodynamics and sound, three hours. — By Mr. J. H. GRACE: Invariants and geometric applications, three hours. — By Mr. E. T. WHITTAKER: The problem of three bodies, three hours.

Lent term, 1905. — By Professor A. R. FORSYTH: Differential geometry, three hours. — By Professor G. H. DARWIN: Dynamical astronomy (elementary), three hours. — By Professor Sir R. S. BALL: Theory of homographic transformation, three hours. — By Professor J. LARMOR: Electrodynamics with optical applications, three hours; Elementary mathematical physics, three hours. — By Professor J. J. THOMSON: Electricity and magnetism, three hours; Discharge

of electricity through gases, two hours. — By Professor B. HOPKINSON: Applied mathematics II, two hours; Electricity II, two hours. — By Dr. E. W. HOBSON: Theory of aggregates and theory of functions of a real variable II, three hours. — By Dr. H. F. BAKER: Theory of functions, three hours; Analysis, three hours. — By Mr. G. B. MATTHEWS: Galois theory, three hours. — By Mr. H. W. RICHMOND: Geometry of curves and surfaces, three hours. — By Mr. H. M. MACDONALD: Aerial and other vibrations, three hours. — By Mr. R. A. HERMAN: Hydrodynamics, two courses, each three hours. — By Mr. A. N. WHITEHEAD: Principles of mathematics, three hours. — By Mr. A. BERRY: Elliptic functions, three hours. — By Mr. C. T. BENNETT: Line geometry, three hours. — By Mr. J. H. GRACE: Invariants and geometric applications II, three hours. — By Mr. E. T. WHITTAKER: Hansen's lunar theory and related planetary theories, three hours. — By Mr. E. W. BARNES: Linear difference equations of the first order, and certain functions derived from them, three hours.

Easter term, 1905. — By Professor A. R. FORSYTH: Differential geometry II, three hours. — By Professor J. LARMOR: Theory of gases and thermodynamics, three hours. — By Professor J. J. THOMSON: Electricity and magnetism, three hours. — By Dr. E. W. HOBSON: Ellipsoidal harmonics, three hours. — By Dr. H. F. BAKER: Theory of functions, three hours; Analysis, three hours. — By Mr. W. L. MOLLISON: Theory of potential and electrostatics, three hours. — By Mr. A. N. WHITEHEAD: Non-euclidean geometry, three hours. — By Mr. A. BERRY: Transformation of elliptic functions, three hours. — By Mr. HARDY: Integral functions, three hours.

OXFORD UNIVERSITY. — *Michaelmas term*, 1904. — By Professor E. B. ELLIOTT: Theory of numbers, two hours; Infinite series and products, two hours. — By Professor W. ESSON: Higher plane curves, three hours. — By Professor A. E. H. LOVE: Harmonic analysis, three hours. — By Mr. J. E. CAMPBELL: Differential equations, two hours. — By Mr. J. W. RUSSELL: Differential calculus, two hours. — By Mr. C. H. THOMPSON: Integral calculus, two hours. — By Mr. E. H. HAYES: Analytical statics, three hours. — By Mr. C. H. SAMPSON: Higher solid geometry, two hours. — By Mr. H. T. GERRANS: Tridimensional rigid dynamics, two hours.

UNIVERSITY OF BRESLAU. — By Professor J. ROSANES: Analytic geometry of space, three hours; Seminar, one hour; Introduction to differential equations, three hours. — By Professor R. STURM: Theory of numbers, three hours; Polyhedra, three hours; History of mathematics, one hour; Seminar, one hour. — By Professor E. NEUMANN: Theoretical optics, four hours.

UNIVERSITY OF ERLANGEN. — By Professor P. GORDAN: Analytic geometry of the plane, four hours; Theory of invariants, four hours; Seminar, three hours. — By Professor M. NOETHER: Differential and integral calculus I, four hours; Analytic mechanics, three hours; Differential geometry, two hours; with exercises, one hour.

UNIVERSITY OF FREIBURG. — By Professor J. LÜROTH: Theory of functions of a complex variable, four hours; Popular astronomy, two hours; Seminar, one hour. — By Professor L. STICKELBERGER: Analytic geometry and differential calculus, five hours; with exercises, two hours; Political arithmetic, two hours. — By Professor A. LOEWY: Analytic geometry of space, four hours; Seminar, two hours. — By Professor K. SEITH: Introduction to algebraic analysis, two hours.

UNIVERSITY OF GIESSEN. — By Professor M. PASCH: Differential and integral calculus, four hours; Selected chapters in plane geometry, three hours; Seminar, one hour. — By Professor E. NETTO: Analytic mechanics, four hours; Elliptic functions, three hours; Seminar, one hour. By ———— (successor to Professor J. Wellstein): Descriptive geometry, six hours; Synthetic geometry, two hours.

UNIVERSITY OF GREIFSWALD. — Py Professor W. THOMÉ: Differential and integral calculus, four hours; Algebraic plane curves, two hours; Seminar, two hours. — By Professor F. ENGEL: Theory of functions, four hours; Theory of transformation groups, four hours; Differential geometry, one hour; Seminar, two hours. — By Professor G. KOWALEWSKI: Mechanics II, four hours; with exercises, one hour; Determinants, two hours; Differential invariants, one hour.

UNIVERSITY OF HALLE. — By Professor G. CANTOR: Analytic mechanics, five hours; Seminar, two hours. — By Professor A. WANGERIN: Synthetic geometry, four hours; Integral calculus with exercises, four hours; Calculus of

variations, two hours; Seminar, two hours. — By Professor V. EBERHARD: Selected chapters in analytic geometry of the plane, with exercises, two hours; Analytic geometry of space, two hours. — By Professor H. GRASSMANN: Calculation with vectors with application to the theory of surfaces, three hours; Elements of descriptive geometry, two hours; with exercises, one hour. — By Dr. C. BUCHHOLZ: Mechanical potential and elements of higher geodesy, two hours. — By Dr. S. BERNSTEIN: Partial differential equations I, hydrodynamics and acoustics, four hours; with exercises, one hour.

UNIVERSITY OF HEIDELBERG. — By Professor L. KOENIGSBERGER: Higher algebra, four hours; Differential equations, two hours; Calculus of variations, one hour; Theory of numbers, one hour; Seminar, two hours. — By Professor M. CANTOR: Differential and integral calculus, four hours; with exercises, one hour; Political arithmetic, two hours. — By Professor K. KOEHLER: Synthetic geometry of space, three hours. — By Dr. K. BOEHM: Elliptic functions, and introduction to the general theory of functions, four hours; Plane and spherical trigonometry, two hours.

UNIVERSITY OF JENA. — By Professor A. GUTZMER: Integral calculus with exercises, five hours; Calculus of variations, four hours; Colloquium, two hours. — By Professor J. THOMAE: Definite integrals, four hours; Differential geometry, four hours; Seminar, two hours. — By Professor G. FREGE: Analytic geometry of space, four hours; Fundamental concepts, two hours. — By Professor R. RAU: Technical mechanics, four hours.

UNIVERSITY OF KIEL. — By Professor L. POCHHAMMER: Theory of numbers, three hours; Theory of functions, three hours; with exercises, one hour. — By Professor P. STÄCKEL: Integral calculus, three hours; Differential geometry, three hours; with exercises, one and one half hours.

UNIVERSITY OF LEIPZIG. — By Professor C. NEUMANN: Potential and spherical harmonics, four hours; Seminar, two hours. — By Professor A. MAYER: Calculus of variations, five hours; with exercises, one hour. — By Professor O. HÖLDER: Mechanics, four hours; Theory of numbers, two hours; Seminar, one hour. — By Professor F. HAUSDORFF: Differential and integral calculus, four hours; with exercises, one hour.—

By Dr. H. LIEBMANN: Analytic geometry of space, two hours; Determinants, two hours. — By Professor K. ROHN (of Dresden): Projective geometry, two hours.

UNIVERSITY OF MARBURG. — By Professor K. HENSEL: Theory of elliptic functions, four hours; Algebraic solutions of equations, three hours; Non-euclidean geometry, one hour; Seminar, two hours. — By Dr. F. v. DALWIGK: Analytic geometry of space, four hours; Descriptive geometry with exercises, six hours. — By Dr. F. JUNG: General theory of curves and surfaces, four hours.

UNIVERSITY OF MÜNSTER. — By Professor W. KILLING: Analytic geometry II, three hours; with exercises, one hour; Elliptic functions, four hours; Seminar, one hour. — By Professor R. v. LILIENTHAL: Analytic mechanics II, four hours; Introduction to the theory of differential equations, four hours; Seminar, one hour. — By Dr. M. DEHN: Descriptive geometry, two hours; Differential and integral calculus, four hours, with exercises, one hour.

UNIVERSITY OF MUNICH. — By Professor G. BAUER: Seminar, two hours. — By Professor F. LINDEMANN: Analytic geometry of the plane, four hours; Ordinary and partial differential equations, four hours; Mathematical basis of insurance, two hours; Seminar, one and one half hours. — By Professor A. VOSS: Algebra, four hours; Applications of the calculus to the theory of surfaces, four hours; Seminar on differential equations, two hours. — By Professor A. PRINGSHEIM: Differential calculus, five hours; Theory of functions, four hours. — By Professor K. DOEHLEMANN: Descriptive geometry I, five hours; with exercises, three hours; Twisted curves of orders 3 and 4, three hours; The imaginary in geometry, one hour. — By Professor E. v. WEBER: Determinants and linear transformations, four hours; Encyclopedia of elementary geometry, three hours; Geometry of the straight line and sphere, two hours.

UNIVERSITY OF ROSTOCK. — By Professor O. STAUDE: Differential and integral calculus, four hours; Differential geometry, four hours; Seminar, two hours.

UNIVERSITY OF TÜBINGEN. — By Professor A. v. BRILL; Introduction to higher mathematics, four hours; Nonrigid systems and the mechanics of Hertz, three hours; Seminar, two

hours. — By Professor H. STAHL: Higher algebra, three hours; Application to the theory of functions, three hours; Seminar, two hours. — By Professor L. MAURER: Hydrodynamics, three hours; Theory of potential, two hours. — By Dr. L. GANS: Partial differential equations of physics, two hours.

UNIVERSITY OF WÜRZBURG. — By Professor F. PRYM: Theory of functions of a complex variable, four hours; Theory of numbers, two hours; Seminar, two hours. — By Professor E. SELLING: Differential and integral calculus, four hours; Planetary orbits, three hours. — By Professor G. ROST: Descriptive geometry, four hours; Analytic mechanics I, four hours; Algebra, four hours; Seminar, four hours.

UNIVERSITY OF INNSBRUCK. — By Professor O. STOLZ: Double integrals and elements of the calculus of variations, three hours; Theory of functions, three hours; Seminar, one hour. — By Professor K. ZINDLER: Algebra and theory of determinants, three hours; Differential equations, three hours; Selected chapters from elementary geometry, one hour.

UNIVERSITY OF STOCKHOLM. — By Professor G. MITTAG-LEFFLER: Elements of the theory of analytic functions. — By Professor H. VON KOCH: Integration of differential equations; Differential calculus. — By Professor V. BJERKNES: Electricity and magnetism. — By Professor I. FREDHOLM: Rational mechanics. — Each course is given three times a week.

THE philosophical faculty of Göttingen proposes for 1907 the following prize subject:

The entropy function introduced by Clausius in his work on thermodynamics has acquired a far-reaching and profound significance through the labors of Gibbs, Planck, Boltzmann, Lorentz and others. The faculty desires a connected exposition of the rôle which this function plays in the domains of physics and chemistry, and an investigation of the diverse mechanical and electrodynamic interpretations of the entropy. Contributions should be submitted under the usual conditions by August 31, 1906.

THE prize offered by the philosophical faculty of Breslau for 1903, for a contribution to the theory of quadric surfaces of revolution has been awarded to Mr. MÜTH of Breslau.

THE Belgian academy of sciences announces as its prize problem of 1905:

To determine the properties of the cubic line complex, especially that expressed by an equation of the form $xyz = kx'y'z'$, wherein x, y, z, x', y', z' are linear expressions in line coördinates.

THE Lobachevsky prize for 1903 was awarded to Professor D. HILBERT for the second edition of his Foundations of Geometry. Honorable mention was made of the memoirs of Messrs. Barbarin, Lemoine, Pieri and Study. The prize will next be awarded November 4, 1906 and competing memoirs must be received by the Physico-mathematical society of Kazan not later than November 4, 1905.

A MEDALLION in memory of the late Sir GEORGE GABRIEL STOKES, which has been erected in the north aisle of the choir of Westminster Abbey, was unveiled July 7 by the Duke of Devonshire, chancellor of the University of Cambridge, and formally transferred to the authorities of the Abbey. Addresses were made by Sir William Huggins, Lord Rayleigh, and Lord Kelvin.

ACTIVE steps have been taken by Trinity College, Dublin, to prepare a suitable memorial for the late GEORGE SALMON.

PROFESSOR F. KLEIN, of Göttingen, has been elected honorary member, and Professor W. F. OSGOOD, of Harvard, has been elected a member of the American academy of sciences, at Boston.

PROFESSOR G. LANDSBERG, of Heidelberg, and Professor J. WELLSTEIN, of Giessen, have been appointed professors of mathematics at the University of Strassburg.

PROFESSOR C. RUNGE, of Hannover, has been appointed associate professor of mathematics at the University of Göttingen.

PROFESSOR C. CRANZ, of Stuttgart, has been appointed professor of mathematics in the military academy at Charlottenburg.

PROFESSOR G. CANTOR has recently celebrated the twenty-fifth anniversary of his professorship of mathematics at the University of Halle.

AT the University of Kiev, Russia, Dr. I. I. KOSSONOGOF and Dr. P. V. VORONETZ have been promoted to assistant professorships of mathematics.

PROFESSOR H. v. MANGOLDT, of the technical high school at Aachen, and Professor F. SCHILLING, of the University of Göttingen, have been appointed professors of mathematics at the new technical high school at Danzig; the former was also appointed rector.

DR. F. EXNER and Dr. J. VALENTIN have been appointed docents in mathematics at the University of Vienna.

PROFESSOR T. F. HOLGATE, of Northwestern University, has been made acting president of the university.

AT Columbia University Associate Professor C. J. KEYSER has been promoted to a full professorship of mathematics.

MR. J. N. JAMES has been appointed professor of mathematics in Epworth University, Oklahoma, O. T.

PROFESSOR R. E. MORITZ, of the University of Nebraska, has been appointed head of the department of mathematics in the University of Washington, succeeding Professor A. RANUM, who has been appointed instructor in mathematics at the University of Wisconsin.

AT Oberlin College Mr. W. D. CAIRNS has been promoted to an associate professorship in mathematics, and Mr. R. V. HILL has been appointed tutor in mathematics.

PROFESSOR T. F. NICHOLS, of Hamilton College, has been promoted to a full professorship of applied mathematics.

DR. G. H. HALLETT has been promoted to an assistan professorship of mathematics at the University of Pennsylvania.

MR. C. A. HOLDEN has been appointed assistant professor of mathematics at Dartmouth College.

MR. J. J. SKINNER has resigned his position as assistant professor of mathematics in the Massachusetts Institute of Technology.

AT the University of Michigan Dr. J. W. BRADSHAW and Dr. L. C. KARPINSKI have been appointed instructors in mathematics.

MR. C. H. SISAM has been appointed instructor in mathematics at the U. S. Naval Academy, Annapolis. Dr. CARL GUNDERSEN has been appointed instructor in mathematics in the Michigan Agricultural College. Miss M. E. SINCLAIR and

Mr. C. HAVEMEYER have been appointed instructors in mathematics at the University of Nebraska. Mr. H. F. HART and Mr. H. A. FREEMAN have been appointed instructors in mathematics in Brown University.

ON August 15 occurred the death of Professor F. G. RADELFINGER, of Columbian University, aged 31 years. He had been a member of the AMERICAN MATHEMATICAL SOCIETY since 1900.

ON May 10 occurred the death of Professor E. SARRAU, of the Ecole polytechnique of Paris. Professor W. WEISS of the German technical school at Prague died June 19, at the age of of 55 years. Professor F. EISENLOHR, of the University of Heidelberg, died on July 21, at the age of 73 years. Professor G. J. ALLMAN of Queen's College, Galway, died recently at the age of 80 years. Professor J. D. EVERETT, of Queen's College, Belfast, died August 9, aged 73 years. Professor C. S. SLONIMSKI, of Warsaw, died in June, at the age of 93 years. The Rev. G. PIRIE, professor of mathematics in the University of Aberdeen, died August 21, at the age of 61 years.

RECENT catalogues of second-hand mathematical works: Joseph Jolowicz, Posen, catalogue No. 149, mathematics and general science, 975 titles; Macmillan and Bowes, Cambridge, England, list No. 302, mathematical and physical works, about 1,700 titles.

NEW PUBLICATIONS.

I. HIGHER MATHEMATICS.

ADHÉMAR (R. D'). Sur une classe d'équations aux dérivées partielles de second ordre, du type hyperbolique, à trois ou quatre variables indépendantes. (Thèse.) Paris, Gauthier-Villars, 1904. 4to. 83 pp.

ANDRÉ (D.). Liste et résumé de mes principaux travaux mathématiques. Paris, Gauthier-Villars, 1904. 8vo. 106 pp. Fr. 4.00

AVRINSKY (N. A.). The theory of probability, with applications to the investigation of the results of measurements and observations. St. Petersburg, 1904. 8vo. 134 pp. (Russian.)

BELTRAMI (E.). Opere matematiche, pubblicate per cura della Facoltà di scienze della r. Università di Roma. (In 4 volumes.) Vol. II. Milano, Hoepli, 1904. 4to. 468 pp. Fr. 20.00

BLIEDNER (E.). Philosophie der Mathematik bei Fries. (Diss.) Jena, 1904.

BRIOSCHI (F.). Opere matematiche, pubblicate per cura del Comitato per le onoranze di F. Brioschi (G. Ascoli, E. Beltrami, G. Colombo, L. Cremona, Negre, Schiaparelli). (In 4 volumes.) Vol. III. Milano, Hoepli, 1904. 4to. 435 pp. Fr. 20.00

CANDY (A. L.). The elements of plane and solid analytic geometry. Boston, Heath, 1904. 12mo. 10 + 248 pp. Cloth.

CATALOGUE international de la litérature scientifique, publié par une Commission internationale sous la direction de H. F. Morley. 1e année. Paris, Gauthier-Villars, 1904. 8vo.
A. Mathématiques. Fr. 18.75
B. Mécanique. Fr. 13.10

CHINI (M.). Corso speciale di matematiche, con numerose applicazioni ad uso principalmente dei chimici e dei naturalisti. Livorno, Giusti, 1904. 8vo. 9 + 259 pp. Fr. 3.80

DAVIS (E.). Die geometrische Addition der Stäbe in der hyperbolischen Geometrie. (Diss.) Greifswald, 1904. 8vo. 74 pp.

DUMAS (G.). Sur les fonctions à caractère algébrique dans le voisinage d'un point donné. (Thèse.) Paris, Rousset, 1904. 4to. 79 pp.

ENCYKLOPÄDIE der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen. Vol. III: Geometrie, herausgegeben von W. F. Meyer. Teil 2, Heft 2: Staude (O.), Flächen 2. Ordnung und ihre Systeme und Durchdringungskurven. Leipzig, Teubner, 1904. 8vo. Pp. 161–256.

ESCLANGON (E.). Les fonctions quasi-périodiques. (Thèse.) Paris, Gauthier-Villars, 1904. 4to. 288 pp.

FIELD (P.). On the forms of unicursal quintic curves. (Diss., Cornell University, June, 1902.) Baltimore, Friedenwald Co., 1904. 4to. 15 pp., 14 plates. (*American Journal of Mathematics.*)

FIODOROV (E.). Elements of the differential and integral calculus. St. Petersburg, 1904. 8vo. (Russian.) M. 9.00

FISCHER (V.). Vektordifferentiation und Vektorintegration. Leipzig, Barth, 1904. 8vo. 6 + 82 pp. M. 3.00

FOUËT (E. A.). Leçons élémentaires sur la théorie des fonctions analytiques. Deuxième partie: Théorèmes d'existence; étude des fonctions analytiques au point de vue de Cauchy, de Weierstrass, de Riemann. Paris, Gauthier-Villars, 1904. 8vo. 11 + 300 pp. Fr. 10.00

FRANCHIS (M. DE). Sulle proiezioni mongiane e stereoscopiche delle curve algebriche. Messina, Trimarchi, 1904. 8vo. 8 pp.

GAUSS (C. F.). Die vier Beweise für die Zerlegung ganzer algebraischer Functionen in reelle Factoren 1. oder 2. Grades. (1799–1849.) Herausgegeben von E. Netto. 2te Auflage. Leipzig, Engelmann, 1904. 12mo. 82 pp., 1 plate. Half leather. (Ostwald's Klassiker der exakten Wissenschaften, No. 14.) M. 1.50

GENOCCHI (A). Differential calculus and elements of the integral calculus, edited by G. Peano. Translated into Russian by N. S. Sineokov. Kiev, 1903. 8vo. 401 pp. (Russian.) M. 6.00

GHIGI (G.). Di una curva piana di quarto ordine. Firenze, Ramella, 1904. 8vo. 16 pp., 1 plate.

GOURSAT (E.). Cours d'analyse mathématique. Vol. II: Fonctions analytiques; équations différentielles; équations aux dérivées partielles; éléments de calcul des variations. Fascicule 1. Paris, Gauthier-Villars, 1904. 8vo. Pp. 1–304.

GROSSMANN (M.). Die fundamentalen Konstruktionen der nichteuklidischen Geometrie. (Progr.) Frauenfeld, Huber, 1904. 4to. 38 pp.

HAGEN (J. G.). Synopsis der höheren Mathematik. (In 4 Bänden.) Vol. III: Differential- und Integralrechnung. (In 6 Lieferungen.) Lieferung 5. Berlin, Dames, 1904. 4to. Pp. 257–320. M. 5.00

HANCOCK (H.). Lectures on the calculus of variations (the Weierstrass theory). Cincinnati, 1904. 4to. 16 + 292 pp. (University of Cincinnati, Bulletin of mathematics, No. 1.)

HEGER (R.). See SCHLOEMILCH (O.).

HENKE (R.). See SCHLOEMILCH (O.).

HUNTINGTON (E. V.). Sets of independent postulates for the algebra of logic. 4to. 1904. (*Transactions of the American Mathematical Society* 5, pp. 288–309.)

JAECKEL (W.). Ueber Flächen 5. Ordnung mit einer doppelten kubischen Raumkurve. (Diss.) Breslau, 1904. 8vo. 113 pp.

JAEHNIKE (W.). Die anbeschriebenen Kreise des bicentrischen oder Sehnen-Tangentenvierecks und die bicentrische Viereckschar. (Progr.) Bromberg, 1904. 4to. 21 pp.

KHANDRIKOV (M.). Theory of elliptic functions and integrals. St. Petersburg, 1903. 8vo. (Russian.) M. 3.00

KRAEMER (C.). Beitrag zur analytischen Untersuchung sphärischer Kurven. (Diss.) Marburg, 1902. 8vo. 36 pp.

LAFITTE (P. DE). Le carré magique de 3. Solution générale du problème. Paris, Gauthier-Villars, 1904. 8vo. 32 pp. Fr. 1.00

LISSON (C. I.). Curso de calculo infinitesimal. Lima (Peru), Rosey, 1904. 8vo. 286 pp.

LOEWY (A.). See STURM (C.).

LOSEHAND (O.). Ueber Kurven 16. Ordnung und 12. Klasse, die bei einem Problem der Enveloppentheorie auftreten. (Diss.) Kiel, 1904. 8vo. 38 pp., 3 plates.

MAATZ (A.). Zur Geschichte der Polyederkoordinaten. Rostock, 1903. 4to. 44 pp. M. 2.00

MATHEWS (G. B.). See SCOTT (R. F.).

MEYER (W. F.). See ENCYKLOPÄDIE.

MLODZIEJEWSKI (B. K.). Elements of plane analytic geometry. Moscow, 1904. 8vo. 367 pp. (Russian.)

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